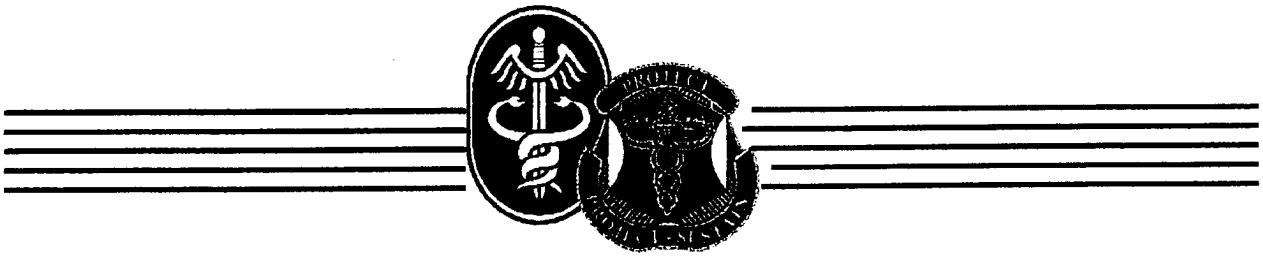
U.S. ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE



TECHNICAL REPORT NO. T98-26
DATE September 1998
AD Accession No.

CORE TEMPERATURE AND ENERGY EXPENDITURE DURING THE CRUCIBLE EXERCISE AT MARINE CORPS RECRUIT DEPOT, PARRIS ISLAND

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

U.S. ARMY MEDICAL RESEARCH AND MATERIEL COMMAND

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1998	Technical Report

4. TITLE AND SUBTITLE
Core Temperature and Energy Expenditure during the Crucible Exercise at Marine Corps Recruit Depot, Parris Island

5. FUNDING NUMBERS

6. AUTHOR(S)
John W. Castellani, Reed W. Hoyt, Andrew J. Young, James P. DeLany, Richard R. Gonzalez, Catherine O'Brien, James R. Moulton, William R. Santee

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute of Environmental Medicine
Natick, MA 01760-5007

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Same as above

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release: Distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

In January and February, 1998, fifty Marine Recruits (thirty men, twenty women) were studied during the Crucible, a 54 hour training exercise . The purpose of this study was to measure body core temperature and energy expenditure during the Crucible to: 1) assess the risk of hypothermia and 2) determine if ration restrictions should be eased. Core temperature was measured with a Body Core Temperature Monitor and an ingestible temperature sensor. Energy expenditure was measured using the doubly labeled water (D218 0) technique. Energy intake was estimated by collecting Meal Ready to Eat (MRE) ration wrappers saved by each volunteer . Weather data were obtained from portable stations. Results: 1) mean maximum core temperature was 38.51°C (range, 38.15-39.14°C); 2) mean minimum core temperature was 35.97°C (range, 35.28-36.64°C); 3) mean energy expenditure (kcal) over 54-h was 13,790 $\pm$ 410 and 10,635 $\pm$ 315 for the men and women, respectively; 4) mean energy intake for 54-h was 3,200 and 2,600 kcals for the men and women, respectively; 5) mean air temperature was 10.8°C (range, 3.6-18.8°C) in January and 13.8°C (range, 6.3-21.4°C) in February. In conclusion, mean core temperature did not fall to hypothermic levels ($<$ 35.5°C) and the energy deficit was approximately 10,100 kcal in the men and 7,700 kcal in the women. However, two cases of hypothermia were reported among Recruits not participating in the testing during the January 1998 Crucible and there were several individuals whose core temperature fell below 35.5°C. Thus, there may be some risk of hypothermia during winter at Parris Island, especially when weather conditions are colder than those prevalent during this study. Further studies during iterations of Crucible during more severe cold conditions are warranted. Recommendations: 1) standardize procedures and guidelines to prevent cold injury during Crucible in a simple set of SOPs, 2) continue rigorous medical surveillance, unrestricted food intake, normal sleep, and reduced strenuous training activities during the four days preceding Crucible, 3) continue easy access to carbohydrate supplemented beverages ,exchange wet for dry uniforms, periodically rewarm in heated tents, and continue to closely monitor Recruits for signs of cold injury.

14. SUBJECT TERMS
Core temperature, hypothermia, hyperthermia, energy expenditure, Marines, doubly labelled water, Crucible, exercise, cold stress

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENTS

This study would not have been possible without the support of the Marine Corps Recruit Depot, Parris Island, South Carolina chain of command. We are particularly indebted to Brigadier General James R. Battaglini and Lieutenant Colonel Michael Becker for their professional contribution to this research effort. Special thanks go to the men and women recruits who participated in this study.

EXECUTIVE SUMMARY

In January and February, 1998, fifty Marine Recruits (thirty men, twenty women) were studied during the Crucible, a 54 hour training exercise which culminates Marine Corps Recruit Basic Training. The purpose of this study was to measure body core temperature and energy expenditure during the Crucible to: 1) assess the risk of hypothermia and 2) determine if ration restrictions should be eased. Core temperature was measured with a lightweight (3 oz) Body Core Temperature Monitor (BCTM) and an FDA-approved ingestible temperature sensor. Energy expenditure was measured using the doubly labeled water ($D_2{}^{18}0$) technique. Energy intake was estimated by collecting Meal Ready to Eat (MRE) ration wrappers saved by each volunteer during the exercise. Weather data were obtained from portable stations. Results: 1) mean maximum core temperature was 38.51°C (range, 38.15-39.14°C); 2) mean minimum core temperature was 35.97°C (range, 35.28-36.64°C); 3) mean energy expenditure (kcal) over 54-h was 13,790 ± 410 (6128 kcal/day) and 10,635 ± 315 (4727 kcal/day) for the men and women, respectively; 4) mean energy intake for 54-h was 3,200 and 2,600 kcals for the men and women, respectively; 5) mean air temperature was 10.8°C (range, 3.6-18.8°C) in January and 13.8°C (range, 6.3-21.4°C) in February. In conclusion, mean core temperature did not fall to hypothermic levels (< 35.5°C) and the energy deficit was approximately 10,100 kcal in the men and 7,700 kcal in the women. However, two cases of hypothermia were reported among Recruits not participating in the testing during the January 1998 Crucible and during January and February there were several individuals whose core temperature fell below 35.5°C. Thus, there may be some risk of hypothermia during winter at Parris Island, especially when weather conditions are colder than those prevalent during this study. Further studies during iterations of Crucible during more severe cold conditions are warranted. Recommendations: 1) standardize procedures and guidelines to prevent cold injury during Crucible in a simple set of SOPs, 2) continue rigorous medical surveillance, unrestricted food intake, normal sleep, and reduced strenuous training activities during the four days preceding Crucible, 3) continue easy access to carbohydrate supplemented beverages (some warm), frequently exchange wet for dry uniforms, periodically rewarm in heated tents, and continue to closely monitor Recruits by instructors and corpsmen for signs of developing cold injury during the Crucible.

INTRODUCTION

Recently, the United States Marine Corps instituted a rigorous event near the end of Recruit training called the Crucible. The Crucible is a 54 hour event consisting of various military tasks and team building exercises designed to simulate intensity and stress associated with a sustained combat operation. The Crucible consists of 6 events with multiple exercises within each event. Exercises include strenuous activities such as an infiltration course, a resupply mission, and a sprint to a firing range. Other low metabolic cost events are also incorporated including a leadership reaction course, various Warrior stations (obstacles, problem solving), and discussions of Marine Core values. Due to the nature and tempo of the Crucible, the Recruits sustain high energy expenditure with minimal sleep (4 hours per night), and food intake is restricted to 2.5 Meals Ready to Eat (MRE) over the 54 hour period. The interaction of fatigue and environmental exposure may increase susceptibility of the Marine Recruits to hypothermia (Young et al., 1998). Indeed, there have been several reported cases of hypothermia (core temperature below 95°F) during the Crucible.

The U.S. Army Research Institute of Environmental Medicine (USARIEM) was tasked by the Commanding General, Marine Corps Recruit Depot (MCRD), Parris Island, SC to analyze Recruit training during Crucible Exercises in the winter months at Parris Island to determine if the Recruits are at risk of hypothermia. USARIEM was also asked to determine the energy expenditure of Recruits to determine if ration restrictions were too severe.

The objectives of this study were to 1) use ingestible temperature sensors to measure body core temperature during the Crucible, 2) use doubly labeled water ($D_2{}^{18}0$) to measure energy expenditure, 3) collect MRE wrappers and fluid intake data to determine energy intake, 4) use the data to make recommendations to the Commanding General, MCRD, Parris Island.

METHODS

A. TEST VOLUNTEERS

50 U.S. Marine Recruits (30 men, 20 women) volunteered for this study during

29-31 January, 1998 and 19-21 February, 1998. All volunteers were training at MCRD, Parris Island, SC. The volunteers who participated gave their free and informed consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research. Volunteer Agreement Affidavit's were signed by each volunteer.

B. PRELIMINARY MEASUREMENTS

Nude weight was measured before and after completing the Crucible. Load weight (pre-Crucible) was measured with the volunteers in full Battle Dress Uniform with load carrying equipment, weapon, helmet, and backpack. Percent body fat was calculated from four (biceps, triceps, subscapular, suprailiac) skinfold sites using the equation of Durnin and Womersley (1974).

C. TEMPERATURE MEASUREMENTS

The core temperature was measured by an ingestible temperature telemetry sensor. Volunteers swallowed an FDA-approved temperature sensor (CorTemp™, Human Technologies Inc., St. Petersburg, FL) which transmitted a 260kHz signal to a Body Core Temperature Monitor (BCTM, Personal Electronic Devices, Inc., Wellesley, MA). The frequency of the pill varies with core temperature. The validity of the pill/BCTM system has been confirmed in recent studies in both hot (Kolka et al., 1993, Sparling et al., 1993) and cold (O'Brien et al., 1997) environments.

D. ENERGY EXPENDITURE/ENERGY INTAKE MEASUREMENTS

Energy expenditure was assessed by the doubly labeled water technique (DeLany et al., 1989). Between 1300 and 1600 on the Wednesday before each Crucible training period subjects provided a baseline urine sample and then the men ingested 9 g of deuterium oxide (D_20) and 11.5 g of heavy oxygen ($H_2{}^{18}O$) and women ingested 8 g of D_20 and 9 g of $H_2{}^{18}O$. Urine was then serially collected at 0200 on Day 1 (Thursday), 2300 on Day 1, 2300 on Day 2 (Friday), and at 0830 on Day 3 (Saturday) following completion of the 54-h training period.

Energy intake was indirectly estimated by collecting the ration wrappers from the MRE's consumed by each individual and tabulating the published kilocalorie content of each food item, making the assumption that the entire item had been consumed. That

value was added to the energy intake estimated from records of the amount of carbohydrate drinks consumed during the 54-h period; volunteers kept written records of water and sports beverages consumed throughout the Crucible.

E. WEATHER DATA COLLECTION

Ambient temperature, relative humidity, and wind speed were measured every 15 min using portable weather stations.

RESULTS

A. VOLUNTEER DATA

Volunteer characteristics are summarized in Table 1.

B. WEATHER DATA

The environmental conditions over the 54 hours of the Crucible are presented in Table 2.

C. CORE TEMPERATURE DATA

January

The highest core temperature occurred during the infiltration course event in 50% (6/12) of the volunteers, and during the night hike in 25% (3/12) of the volunteers. The lowest core temperatures occurred during sleep in 83% (10/12) of the volunteers. The mean temperatures are presented in Table 3.

February

In 50% of the volunteers, the highest core temperature occurred during the infiltration course event, 14% occurred during the hike out to the Crucible training site and 14% occurred during the resupply course (Event 4). In 64% of the volunteers, the lowest core temperatures occurred during sleep and another 14% occurred during the hike out. The mean temperatures are presented in Table 3.

Figure 1 presents the average change in core temperature ($°C \cdot hr^{-1}$) for 8 different

Table 1. Physical characteristics (mean ± S.D.) of men and women Marine recruits (50 volunteers).

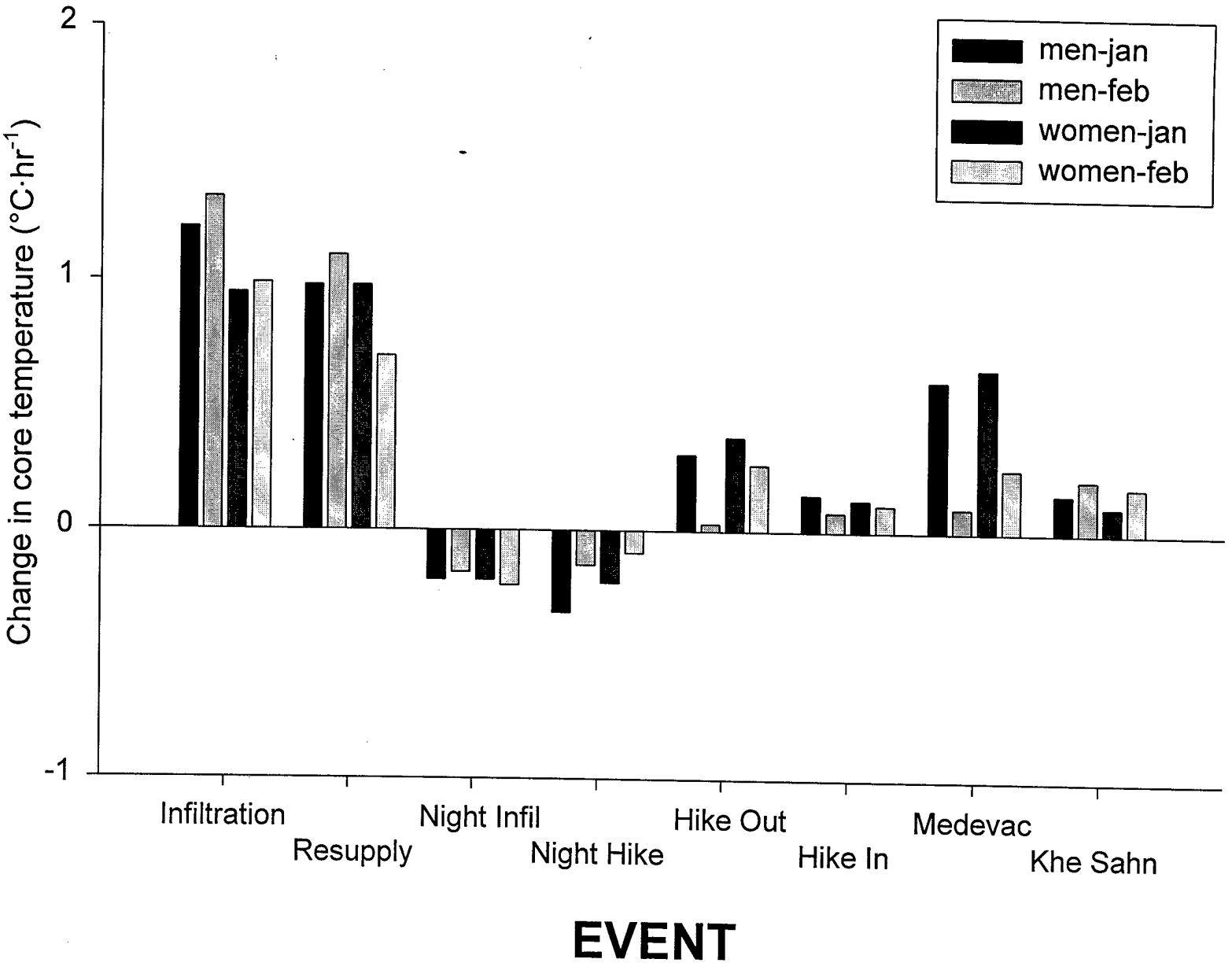
		Age (yr)	Height (cm)	Pre-Nude Weight (kg)	Post-Nude Weight (kg)	Change in weight (kg)	Load Carried (kg)	Surface Area (m^2)	Body fat (%)
Men									
	January (N = 15)	19.9 ± 2.4	174.8 ± 5.7	74.7 ± 8.3	71.5 ± 8.0	-3.2 ± 1.0	30.2 ± 0.9	1.88 ± 0.12	16.0 ± 3.0
	February (N = 15)	20.1 ± 1.6	173.5 ± 5.1	72.9 ± 7.3	70.0 ± 7.5	-3.0 ± 0.5	28.9 ± 1.4	1.85 ± 0.11	15.3 ± 3.4
	All Men (N = 30)	20.0 ± 2.1	174.1 ± 5.4	73.8 ± 7.9	70.8 ± 7.8	-3.1 ± 0.8	29.5 ± 1.3	1.87 ± 0.12	15.7 ± 3.2
Women									
	January (N = 10)	19.1 ± 0.9	160.3 ± 6.3	58.1 ± 9.7	56.6 ± 9.7	-1.6 ± 0.3	29.4 ± 0.9	1.59 ± 0.14	26.1 ± 4.1
	February (N = 10)	20.5 ± 3.1	164.5 ± 6.5	59.1 ± 6.1	57.4 ± 6.2	-1.7 ± 0.7	28.1 ± 1.0	1.63 ± 0.11	26.5 ± 1.7
	All Women (N = 20)	19.8 ± 2.4	162.4 ± 6.8	58.6 ± 8.1	57.0 ± 8.2	-1.6 ± 0.5	28.7 ± 1.1	1.61 ± 0.13	26.3 ± 3.1
All	(N = 50)	19.9 ± 2.2	169.4 ± 8.3	67.7 ± 10.9	65.2 ± 10.5	-2.5 ± 1.0	29.2 ± 1.3	1.77 ± 0.18	19.9 ± 6.1

Table 2. Weather data during 54 hour Crucible event.

		Mean	Range
January			
	Temperature (°C)	10.8	3.6-18.8
	Relative Humidity (%)	70	34-96
	Wind Speed (mph)	3.1	1.0-7.1
	Rain	None	
February			
	Temperature (°C)	13.8	6.3-21.4
	Relative Humidity (%)	72	37-99
	Wind Speed (mph)	3.1	0.5-6.9
	Rain	Trace	

Table 3. High and low core temperatures (mean) of men and women Marine recruits.

		Mean High	Range	Mean Low	Range
Men					
	January (n=7)	38.51	38.15-38.56	35.63	35.28-36.39
	February (n=7)	38.69	38.33-39.14	36.13	35.43-36.64
	All Men (n=14)	38.51	38.15-39.14	35.88	35.28-36.64
Women					
	January (n=5)	38.51	38.30-38.76	36.12	35.68-36.51
	February (n=7)	38.53	38.15-38.89	36.08	35.68-36.51
	All Women (n=12)	38.52	38.15-38.09	36.08	35.68-36.51
All	(n=26)	38.51	38.15-39.14	35.97	35.28-36.64


men-jan
men-feb
women-jan
women-feb
Change in core temperature (°C·hr-1)
2
1
0
-1
Infiltration
Resupply
Night Infil
Night Hike
Hike Out
Hike In
Medevac
Khe Sahn
EVENT

Crucible events. The greatest changes in body temperature occurred during the infiltration course (Event 1) and the resupply course (Event 4). Small negative changes were observed during the night events (night infiltration, night hike). The Medevac event in January also demonstrated a high rate of increase in core temperature (0.61-0.66°C·hr^{-1}).

D. ENERGY EXPENDITURE

Energy expenditure (EE), determined using the doubly labeled water technique, for the men and women, is shown in Table 4.

E. ENERGY INTAKE

January

The mean (± S.E.) energy intake over 54-h was 3343 ± 1215 kcal for the men (n = 12) and 2592 ± 523 kcal for the women (n = 7).

February

The mean (± S.E.) energy intake for the men (n = 15) was 3135 ± 957 kcal over 54-h. For the women (n = 10), it was 2568 ± 1207 kcal.

DISCUSSION

The purpose of this study was to determine if Marine Recruits experience low body core temperatures during the Crucible. A secondary purpose was to determine the energy expenditure and intake of Recruits over the 54-h event to determine the magnitude of the energy deficit.

There were no cases of hypothermia in the Recruits we measured, in either January or February. However, in a few individuals, core temperature did fall as low as 35.3-35.5°C. This finding is surprising in light of the moderate ambient temperatures prevalent during data collection. As well, during the January Crucible, medical personnel reported observing hypothermia (body core < 35°C) in two Recruits who

Table 4. Mean (± S.E.) energy expenditure ($D_2{}^{18}O$) during January and February, 1998 Crucible.

	kcal/day	kcal/day/kg	kcal/55-h	kcal/55-h/kg
Men (n = 29)	6,129 ± 182	83 ± 2	13,790 ± 410	187 ± 5
Women (n = 20)	4,727 ± 140	82 ± 3	10,635 ± 315	184 ± 7
All (n = 49)	5,556 ± 156	83 ± 2	12,502 ± 350	186 ± 4

were not participating in our study. Therefore, hypothermia may be a risk during winter Crucible, especially in cold or rainy conditions more severe than those prevalent in these studies.

The lowest core temperatures primarily occurred during sleep. This is not unexpected and reflects the normal circadian variation in human core temperatures. However, it may be that the low values we observed also reflected the fatiguing nature of the Crucible. Ranger school students also have been reported to exhibit a reduction in basal core temperature after 61 days of strenuous training (Young et al., 1998). One potential way to somewhat ameliorate a fall in core temperature during sleep might be to have Recruits eat before going to bed during the most severe cold conditions (see Appendix A). This will also improve morale. Increases in endogenous heat production may also inhibit shivering, thus allowing the Recruits to better sleep. Recruits could also wear extra clothing during sleep.

Another important observation from the current study is that core temperatures increased to ~39°C in a few individuals. Therefore, during Crucible in the hotter months (April-October), hyperthermia may be a hazard. Water deficit (that is, water loss exceeding water intake) during the winter Crucible exercises that we studied was estimated to be around 1.6 kg, so dehydration may become a concern during the warmer months. Appropriate water doctrine should be promulgated to lessen the possibility of dehydration and hyponatremia (Latzka et al. 1998).

The energy deficit over the 54-h period of the Crucible was approximately 10,100 kcals for the men (~ 4400 kcal/day) and 7,700 kcals (~ 3400 kcal/day) for the women. This deficit could account for 42% of the weight loss observed in the men and 63% in the women. Such a deficit is likely to have a minimal effect over the 54-h period of the Crucible, although if this deficit were sustained it could impair thermoregulation in the cold (Young et al, 1998).

The male recruits in the present studies had about 16% body fat, body weights of about 74 kg, with fat energy reserves of about 63,000 kcal. Fat energy reserves were calculated assuming a body fat energy density of 7700 kcal/kg, and that a minimum of 5% body fat or about 3.7 kg of fat is needed for normal physiological function (Friedl et al., 1994). This fat energy reserve, which constitutes about 98% of the body's energy reserve (Sahlin, 1986), is enough energy to meet a 4,400 kcal/day deficit for two weeks. The women, with smaller energy deficits and somewhat larger

available body fat, could sustain their 3,700 kcal/d deficits for about 20 days.

Because the environmental conditions during the Crucible study periods were not cold and/or rainy, models (Tikuisis et al., 1987; Tikuisis et al, 1988; Tikuisis and Frim, 1994) were used to predict core temperature during 50 minutes of low crawling (simulate Infiltration and Resupply events) in wet and dry conditions at an ambient temperature of 35°F. These models predicted (Tables 5, 6), that under these conditions, there should be no fall in core temperature in dry conditions and a small, tolerable fall in core temperature when it is raining or the course is wet. Predictions were computed for average men and women tested during the two Crucible iterations (Group I) as well as for the "worst-case" individuals who are small and least fat (Group II). The survival time estimates shown in table 6 clearly illustrate that the smallest, least fat individuals are at greater risk and will cool more rapidly in cold, wet conditions than their larger, fatter cohorts.

RECOMMENDATIONS

a. The following procedures in place at MCRD should be continued to prevent cold injury during Crucible in winter:

(1) During the four days preceding Crucible, rigorous medical surveillance, unrestricted food intake, normal sleep, and reduced strenuous training activities will help ensure that Recruits begin the exercise healthy, well fed and rested, and will optimize resistance to cold injury.

(2) The Recruits should continue to have easy access to carbohydrate supplemented beverages (some warm), frequently exchange wet for dry uniforms, periodically rewarm in heated tents, and be closely monitored by instructors and corpsmen for signs of developing cold injury during the Crucible.

b. The following countermeasures should be considered for implementation

Table 5. Predicted core and skin temperatures (°C) at end of 50 min low crawl exercise at 2 ambient temperatures in dry clothing with no water immersion.

	Air Temperature (35°F)	Air Temperature (45°F)
Group I Men		
Rectal temperature (°C)	37.6	37.6
Skin temperature (°C)	28.2	26.2
Group II Men		
Rectal temperature (°C)	37.5	37.5
Skin temperature (°C)	22.5	26.1
Group I Women		
Rectal temperature (°C)	37.6	37.6
Skin temperature (°C)	26.2	29.1
Group II Women		
Rectal temperature (°C)	37.1	36.9
Skin temperature (°C)	22.1	21.0

Group I denotes average body weight, height and percent fat from two Crucible iterations. Group II denotes volunteers with lowest body weight and % body fat (men, 61 kg, 8% fat; women, 45 kg, 20% fat). Wind, calm. Battle Dress Uniform (dry).

Table 6. Prediction of survival time (hours) until critical hypothermia at various immersion levels in normal and lean recruits.

Immersion Level	Group I Men	Group II Men (lean)
No Immersion	11.3	7.6
Knee	7.7	4.9
Thigh	4.6	2.9
Mid-Chest	3.1	2.0
	Group I Women	**Group II Women (lean)**
No Immersion	12.6	8.0
Knee	8.8	5.3
Thigh	5.4	3.1
Mid-Chest	3.7	2.1

Group I denotes average body weight, height and percent fat from two Crucible iterations. Group II denotes volunteers with lowest body weight and % body fat (men, 61 kg, 8% fat; women, 45 kg, 20% fat).

during winter Crucible under the most severe conditions (below 20°F wind-chill temperature, course wet or dry; below 30°F, course wet, see Appendix A).

(1) Establish a Recruit "buddy-system" to watch for the signs of developing cold injury. Attempt to pair smaller, leaner "at risk" Recruits with larger, heavier Recruits.

(2) Provide a hot snack, e.g. soup, oatmeal, after Recruits complete night activities and return to sea huts during the most severe cold conditions. This will improve morale, prevent Recruits from isolating and withdrawing from other people, and may lead to better quality sleep.

c. Standardize procedures and guidelines to prevent cold injury during Crucible in a simple set of SOPs. USARIEM staff have prepared a simplified revision of the MCRD's current guidance for consideration (see Appendix A).

d. USARIEM staff believe that wire hazards and water obstacles encountered during some events pose no undue hazard to the Recruits during winter as long as intermittent rewarming and exchange of wet for dry uniforms is provided following those events. Further, caloric deficit developed over the 54 hour Crucible is not excessive, and its alleviation will not substantially alter the risk of cold injury during Crucible.

e. USARIEM should measure body temperatures of Recruits completing Crucible during more severe cold weather than studied to date, in order to document the magnitude, if any, of cold strain and confirm that guideline employed at MCRD Parris Island are appropriate.

REFERENCES

DeLany, J.P., D.A. Schoeller, R.W. Hoyt, E.W. Askew, and M.A. Sharp. Field use of D_2O^{18} to measure energy expenditure of soldiers at different energy intakes. J. Appl. Physiol. 67: 1922-1929, 1989.

Durnin, J.V.G.A., and J. Womersley. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Brit. J. Nutr. 32: 77-97, 1974.

Friedl, K.E., R.J. Moore, L.E. Martinez-Loez, J.A. Vogel, E.W. Askew, L.J. Marchitelli, R.W. Hoyt, and C.C. Gordon. Lower limit of body fat in healthy active men. J. Appl. Physiol. 77:933-940, 1994.

Kolka, M.A., M.D. Quiqley, L.A. Blanchard, D.A. Toyota, and L.A. Stephenson. Validation of a temperature telemetry system during moderate and strenuous exercise. J. Therm. Biol. 18: 203-310, 1993.

Latzka, W.A., S.J. Montain, and M.N. Sawka. Fluid replacement recommendations for training in hot weather. USARIEM Technical Report T98-17, April 1998.

O'Brien, C. , R.W. Hoyt, M.J. Buller, J.W. Castellani, and A.J. Young. Telemetry pill measurement of core temperature in humans during active heating and cooling. Med. Sci. Sports Exerc. 30: 468-472. 1998.

Sahlin, K. Metabolic changes limiting muscle performance. In: Biochemistry of Exercise VI. International Series on Sports Sciences. 16:323-344, 1986.

Sparling, P.B., T.K. Snow, and M.L. Millard-Stafford. Monitoring core temperature during exercise: ingestible sensor vs. rectal thermistor. Aviat. Space Environ. Med. 64: 760-763, 1993.

Tikuisis, P., and J. Frim. Prediction of survival time in cold air. DCIEM Report No. 94-29, North York, Canada.1994.

Tikuisis,P., R.R. Gonzalez, R.A. Oster, and K.B. Pandolf. Role of body fat in the prediction of metabolic response for immersion in cold water. Undersea Biomedical Res. 15:123-134,1988.

Tikuisis, P., R.R. Gonzalez, and K.B. Pandolf. Human thermoregulatory model for whole body immersion in water at 20 and 28°C. Technical Report T23-87, U.S. Army Research Institute of Environmental Medicine, Natick, MA, June, I987.

Young, A.J., J.W. Castellani, C. O'Brien, R.L. Shippee, P. Tikuisis, L.G. Meyer, L.A. Blanchard, J.E. Kain, B.S. Cadarette, and M.N. Sawka. Exertional fatigue, sleep loss, and negative energy balance increase susceptibility to hypothermia. J. Appl. Physiol. 1998 (In Press).

APPENDIX A

Preventing Cold Weather Injury During CRUCIBLE at MCRD Parris Island

1. Purpose. To establish a standard operating procedure (SOP) for preventing Cold Weather Injuries among Recruits participating in CRUCIBLE at MCRD Parris Island during winter training cycles (1 Oct - 1 Apr).

2. Background

a. General. Winter weather at MCRD Parris Island is sometimes cold enough to constitute a serious health threat for exposed Recruits. These guidelines are intended to standardize procedures to allow CRUCIBLE to be continued safely during cold weather. However, adherence to SOP cannot substitute for close supervision and, when necessary, corrective intervention by instructors to prevent cold weather injury among Recruits.

b. Environmental Factors. Cold exposure can cause body heat loss and falling body temperatures, especially when it is windy. The Wind-Chill Equivalent Temperature integrates wind and air temperature into a single value which estimates environmental cooling power and risk of cold injury. Water conducts heat from the body faster than air. Therefore, when clothing becomes wet due to rain, splashing water, or sweat, body heat loss accelerates. Recruits crawling through water below 70 °F can experience considerable body heat loss. Also, body heat can be lost rapidly when lying on the bare ground.

c. Responses to Cold. When humans are exposed to cold, the normal responses are to shiver and constrict blood vessels in the skin. Body fat insulates against heat loss, therefore, extremely lean Recruits may be more susceptible to cold and fatter Recruits may shiver less. Fatigued persons are less active and shiver less in the cold, so they produce less body heat. Therefore, CRUCIBLE, with its sustained heavy exertion, restricted rations and limited sleep, may increase the Recruits'

susceptibility to cold injury.

d. Cold Weather Injury (CWI). Recruits may be at risk of cold injuries whenever air temperatures fall below 55 °F, or if they are immersed in water temperatures below 70 °F.

(1) The most serious cold injury likely to occur during cold weather cycle CRUCIBLE at MCRD is ***hypothermia***, a life threatening condition in which deep-body temperature falls below 95° F. Hypothermia is difficult to recognize. Victims often appear exhausted, withdrawn, confused or even drunk. Even mild hypothermia can cause victims to make poor decisions or act bizarrely.

(2) If individuals cannot keep their hands and feet warm and dry, non-freezing cold injuries can occur. ***Chilblain*** can develop in only a few hours. This is characterized by red, swollen skin which is tender, hot to the touch and may itch or feel prickly ("pins and needles"). ***Trenchfoot*** can begin to develop in as little as 12 hours, but usually takes longer. The combination of cold and wet softens skin of the feet, which then may swell, turn blue to black , and feel itchy, numb or tingling.

(3) Freezing cold injuries only occur when air temperature is below 32 °F, so Recruits will not often be at risk for this type of injury during CRUCIBLE at MCRD Parris Island. With ***frostnip***, freezing is limited to the skin surface, but ***frostbite*** extends to deeper tissue. Frostnip is not a serious injury, but it warns of impending frostbite. The skin becomes red and possibly swollen, but there is no permanent damage if the area is rewarmed at this point. With deeper freezing, frostbite develops, and skin becomes numb and turns a grey or waxy-white color. The area will feel cold and stiff. Freezing severely damages tissues and requires emergency medical treatment.

2. Cold Injury Prevention Procedures. Prevention of cold injury during CRUCIBLE at MCRD will be accomplished with a system of three incremental levels of cold warnings progressively activated as cold weather becomes more severe. Cold injury prevention guidelines are specified for each warning level.

a. Cold Warning Levels.

WIND CHILL TEMPERATURE	DRY COURSE	RAIN or WET COURSE
Below 50 °F	Winter Procedures	Cold Alert
Below 30 °F	Cold Alert	Cold Danger
Below 20 °F	Cold Danger	Cold Danger

b. Cold Injury Prevention Guidelines.

(1). Winter Procedures

Clothing Issue: Winter Field Uniform; gloves, ear covering as needed;
Clothing Swap: Exchange wet for dry clothing as needed;
Warming Tent: Rewarming as needed;
Food/Fluid: Encourage fluid intake; offer Hot-Wets;
Event Deviations: none
CWI Surveillance: Drill Instructor check once per 24 hours.

(2). Cold Alert

Clothing Issue: Winter Field Uniform with gloves, ear covering mandatory;
Clothing Swap: Exchange wet for dry clothing immediately after Events 1 & 4;
Warming Tent: 30 minutes rewarming after Events 1 & 4, and for core value discussions;
Food/Fluid: 1 Hot-Wet during rewarming periods and core values discussion;
Event Deviations: Substitute training dummies for Recruit "casualties" during Events 1 & 4;
CWI Surveillance: **ENHF*** once per 12 hours.

(3). Cold Danger

Clothing Issue: Winter Field Uniform with gloves, ear covering mandatory;

Clothing Swap:	Exchange wet for dry clothing immediately after Events 1 & 4 and whenever required;
Warming Tent:	30 minutes rewarming after 4 hours exposure, Events 1 & 4, and for core value discussions;
Food/Fluid:	1 Hot-Wet during rewarming periods and core values discussion; encourage ration heater use; hot cereal/soup on return to sea huts;
Event Deviations:	Substitute training dummies for Recruit "casualties" during Events 1 & 4; avoid water hazards on Events 1 & 4; no facial camouflage;
CWI Surveillance:	**ENHF*** once per 8 hours.

* **ENHF** - Corpsmen check Recruits for CWI including hypothermia and injury to ears, nose, hands and feet.

WIND CHILL CHART

WIND SPEED (IN MPH)	ACTUAL TEMPERATURE (°F)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	EQUIVALENT CHILL TEMPERATURE (°F)											
CALM	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	3	-9	-21	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-32	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-124
25	30	15	0	-15	-29	-44	-59	-74	-89	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-51	-67	-82	-98	-113	-129	-145
40	26	10	-6	-22	-37	-53	-69	-85	-101	-117	-132	-148